Chapter

Blockchain: From Industry 4.0 to the Machine Economy

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Abstract

The extreme automation of our factories is necessary in order to face the Fourth Industrial Revolution. This new industrial paradigm will force our industries to manufacture much shorter and customized series at increasingly competitive prices, even tackling the manufacture of thousands of different configurations of a single base product. In order to achieve this, our production processes must have a flexibility in their configuration that has never been imagined before. This flexibility and ability to adapt automatically to demand are the essence of the Fourth Industrial Revolution and are part of the Western strategy to recover an industrial sector increasingly threatened by the Eastern production of large series at really competitive prices. Based on our participation in more than a dozen proofs of concept in the automotive, aeronautics, agri-food, or energy sectors, we describe the scenarios in which blockchain technology brings the greatest benefits to Industry 4.0. After finishing different experimentations, we carried out an in-depth analysis of the true added value of blockchain in the industry and contrasted our conclusions through interviews with more than 20 people in charge of innovation from different industries. As a result, we have obtained the principal four values of blockchain technology applied to Industry 4.0.

Keywords: blockchain, DLT, Industry 4.0, trust, cyber security, IoT, IIoT, industrial systems

1. Introduction

The automation of our industries and the relationships of the different agents in the value chain will allow us to eliminate many repetitive manual processes with little added value that reduce the competitiveness of the industry [1]. Even the automation of tendering and contracting processes can improve our competitiveness.

Technologies, such as artificial intelligence, flexible robotics, IoT, or augmented reality will allow us to advance in the digitalization and optimization of our processes, but the great barrier to implement a fully automated production systems and especially relationships is precisely the lack of trust and security [2].

Trust is the basis of a new research line that in recent months has had an increasing impact on industrial forums and conferences: blockchain technology. Blockchain is a distributed ledger of transactions and digital events that have been executed and shared among participating parties. Each transaction is consensuated, mathematically linked and stored by the network of participants, thereby achieving its immutability. Blockchain allows us to operate our procedures and relationships in the digital environment in a much more safe and reliable way [3].

The next few years will see a profound transformation of industrial processes, increasing the synchronization between different agents in the value chain, as well as extreme automation of decision-making, all thanks to the reliability offered by blockchain. It is even hoped that in the future, it will be able to transform its own business models, just as in recent decades the Internet has done, which has so far been the most disruptive technology in history.

In this chapter, we will explain the different use cases and scenarios that we consider to have greater potential in the future of Industry 4.0, starting first with generic industrial cases and then analyzing the specific cases of the energy industry. This selection has been made based on the experience of more than a dozen blockchain projects in the domain of Industry 4.0.

Next, we will describe the four main generic values that we have discovered after different proofs of concept with several companies. Finally, we will discuss future lines of research linked to a new concept such as the machine economy and report the final conclusions of the chapter.

2. Bringing blockchain into Industry 4.0

After carrying out different proofs of concept, mainly associated with manufacturing companies, as well as analyzing other experiments carried out by third parties, we expose in a critical way which would be the main application scenarios of the blockchain technology and its benefit for industrial companies.

All the analyzed cases have been contrasted through a working meeting with several companies in order to analyze the real need and utility of them. The following are the use cases that have presented greatest utility in the experimentation process, responding to real needs not covered today in their ecosystems.

2.1 Traceability

The traceability of industrial goods throughout the entire supply chain, including even the life cycle of a product, is one of the applications that according to consulted experts in the experimentation, as well as the level of maturity of the technology in this field, is expected to have a greater impact on the short/medium term of the industry.

For any point in the chain, it is very valuable being able to have visibility of the destination and use of its components; thanks to this information the participant in the supply/value chain will be able to (i) analyze the impact of any change in the design/composition of their product, (ii) anticipate changes in consumption habits/trends, (iii) avoid manually entering details of the products/components received by suppliers, (iv) automate complaints and warranties without the need for paperwork, or even (v) avoid reusing certificates of origin.

We are facing a known need that the big industrial players have wanted to solve on different occasions [4–7]. The large industries have designed and built traceability systems based on traditional (centralized) architectures and have made them available throughout their sectorial supply chain. However, these systems have not been widely accepted, and the only ones that continue to exist are those related to food safety that is mandatory.

The problem with the previous approaches is that the "giant" of the supply chain was the one that offered its system to the rest and was in charge of the custody and coherence of the common database.

This created great reticence because, even if industrial data visibility policies were implemented so that only agreed users/companies could consume certain information, there was a "demigod" in the supply chain which, due to the architecture of the system, could have visibility and exploit the information of the entire value chain. Furthermore, processing the information in a traditional system is very complicated to guarantee the sovereignty and protection of industrial data [8].

The alternative to create a similar system using traditional technologies is to create a clearing house in the supply chain, which has been done in areas such as food safety and is the only area where traceability is complete throughout the chain [9]. However, in this case the actors only submit information related to food safety and cannot consult/exploit the information, so the functionality is not full.

Blockchain makes it possible to eliminate these barriers thanks to a distributed architecture in which there is no "agglutinator" of the contents. Guaranteeing through "contract" and cryptography the visibility and use of data (sovereignty of industrial data) and ensuring that all participants in the network are treated equally.

However, we have detected that an important point in these projects is to maximize and automate as much as possible the capture of data, which is why industrial projects are considering that the Industrial Internet of Things (IIoT) should be the origin of most of the data that are dumped in the traceability chain. Moreover, this information should be signed by means of cryptographic hardware in these IIoT devices, so that the reliability of the data would be extraordinary.

2.2 Interoperability and sovereignty of industrial data

Data and its exploitation are going to be the key in this new industrial paradigm in which we are entering, promoting even service models based on data [10]. That is why it is said that data is the new industrial raw material and its sovereignty is a key point today.

For this reason, several initiatives have arisen that could be called industrial data platform and that aim to manage and share data of industrial processes, as well as create value-added services based on them. The most evolved platforms, such as the one from the international data space consortium, which arose in Germany but is currently the leading European experimental platform, even include application/service marketplaces based on industrial data [11].

Perhaps predictive maintenance together with other cases of data analysis and prescription are the most common and tangible cases today [12], but it is expected that really these platforms are the basis for innovative proposals of business models and industrial services that today we cannot even imagine. However, there is currently a major barrier to the adoption of such platforms, and again it is the reliability of the industrial data and its protection.

Firstly, there are models for selling information related to industrial processes, the value of which will depend on the reliability of such data. Therefore, it is one of the reasons why blockchain begins to be a buzzword in the deliberations on the future of these platforms, since the more reliable the data, the greater will be its value in the market.

On the other hand, these platforms must guarantee the sovereignty of industrial data, for which blockchain architectures/platforms that natively allow confidentiality between parties seem the most promising [13]. Current developments include data encryption models specific to each recipient or set of recipients, such as channels or private data collection in Hyperledger Fabric v1.4.

However, blockchain and smart contracts will even allow to execute algorithms and data processing independently, offering the recipient only the result of its execution [14]. In the future the algorithms can be encoded in a native blockchain program—the smart contract—in such a way that the owner of the algorithms can allow the smart contract to access and process their data and generate insights about them. However, the smart contract provider will not have access to the user's RAW data; this will allow them to offer a service based on the data without the customer having to make a disclosure of such information [15].

After all, it will allow us to put in value the industrial data even without having to expose them to a third party, allowing them nevertheless to execute certain processes on them. This can even be very useful to test/train prediction models of all kinds without endangering the source data, the result of which can then be a high-value algorithm for a specific industry.

2.3 IIoT reliability

One of the main benefits of the blockchain application to IIoT in which all the interviewed experts agree is precisely the decentralized architecture that blockchain can offer to IoT in general and especially to the industrial ecosystem whose requirements are more severe [16].

Currently the architecture of these systems is a classic client/server, which has a series of barriers and deficiencies for an environment such as IoT/IIoT. It is expected that the client/server architecture will not be able to respond to the exponential growth of IIoT and IoT in general; we must bear in mind that we will face an immense number of devices generating and consuming information from third parties. To get an idea of this figure, an industrial control machine or device generates hundreds of millions of data/parameters annually, and inside a medium-sized factory, we can find tens or hundreds of devices.

The cost of centralized processing and even network equipment and connectivity to support such cross traffic between different industrial systems (clients) with dependencies between them would be exponential if all these communications had to pass through a central system (server). In addition, this central system (server) would be a major bottleneck for all connected devices and a single point of failure (SPOF) which, if compromised, could generate a production shutdown of millions of euros in a single factory.

The trend is also that connected machines and factories interact outside their business environment with partners, suppliers, and customers. This brings another set of challenges at the level of identity management and device authentication. Currently within a factory, existing systems have multiple limitations because vendors deploy centralized systems that cannot interact safely and reliably with third parties, even rely on costly and complex in-house or manufacturer-controlled PKI architectures. In a global economy and in an ecosystem relationship, the problem and complexity multiply. Thus, blockchain technology has demonstrated that distributed authentication and identity management are highly efficient and feasible [17] and can solve identity management problems.

For all these reasons, we are dealing with a new paradigm in which, after moving from the traditional server model to an elastic cloud server architecture, we must evolve toward a network of devices in which blockchain is postulated as the main technological enabler. This paradigm shift would lead us toward decentralized registers that could become sectorial or even universal.

But the adoption of blockchain in the IIoT ecosystem, and IoT in general, offers another series of advantages, which although perhaps less disruptive also resolves some of the challenges and barriers to adoption of IIoT and IoT discussed above.

Blockchain offers us a decentralized record of information, which is also reliable and unalterable. That is why besides avoiding the single point of failure of traditional systems, it offers us a more resilient system, not only in terms of system availability, which increases exponentially by avoiding the single point of failure, but also in terms of information, since it provides us with a reliable record [18].

Offering a reliable record of information due to its immutability and ensuring non-repudiation of operations are an enabling factor for transactions between unknown devices or different organizations.

As we have mentioned before, one of the biggest barriers to adopting a higher level of automation in the industrial environment is precisely the mistrust of data, especially data from third parties. Although the industries themselves in many cases do not rely on automating some critical processes based on their own information due to potential sabotages or failures, it is impossible to think that they will do it based on third party information sources.

Blockchain offers reliability over our own information—thanks to the integrity and strong authentication of our issuers—as well as over information provided by third parties. Such reliability will allow greater automation and avoid many of today's low value-added manual processes that are provoked by a lack of confidence in the data.

The decentralization of information and its immutability are also a major advantage for critical industrial infrastructures (chemical, energy, etc.). According to the latest recommendations for critical infrastructure protection like the European Critical Infrastructure Protection (ECIP) or NIST Cybersecurity Framework, they should be able to guarantee the custody of their data in the case of any fortuitous incident (natural disaster, system failure) or deliberate incident (physical and/or logical attack) for forensic analysis.

Nowadays, this custody of information in case of cyber incidents is practically impossible to achieve since the attacker usually stays inside the system 146 days before executing the attack or being detected [19], and one of its objectives is to meticulously study the infrastructure not only to maximize its impact but also to be able to erase any trace once the cyberattack is executed.

This is why traditional backup systems and data replicas are usually eliminated during the attack; however, if the infrastructure was connected to a blockchain network, the attacker would have to completely erase each and every one of the nodes of the distributed blockchain network to make their footprints disappear, something totally unthinkable. In fact, during all the time that the attacker remains investigating, the infrastructure is erasing his trail, so a simple periodic comparison of the logs of the infrastructure itself against its unalterable copy in blockchain could alert us of the existence of an intruder in the network or detect any change in the machine code of our industrial devices.

However, although blockchain is postulated as the solution to IIoT's architectural design problems, it must be kept in mind that current solutions and ledgers must evolve in order to respond to the needs of IIoT devices in real time (low latency, bandwidth, message size). That is why in the blockchain, ecosystem begins to emerge new developments and technologies aimed at overcoming this barrier [20–22]. If this is achieved, the potential market and technological impact could lead to the long-awaited paradigm shift we were talking about earlier.

3. A new energy industry

In the last years, the energy sector has initiated a major transformation of the electricity grid, the industrial infrastructure responsible for transporting and distribution electricity from the generation plants to the consumer. The smart grid is a much more automated and resilient grid and offers unprecedented levels of reliability and service continuity.

3.1 Energy sector considerations regarding the previous section

The smart grid itself is a network of IIoT devices and is also considered a critical infrastructure, so everything mentioned above about the advantages of using blockchain in IIoT devices obviously applies directly to this industry.

Traceability is also relevant in the energy industry; therefore, at the end of 2018 ACCIONA announced, in collaboration with Tecnalia, the first proof of concept for the use of blockchain to trace the renewable origin of energy. In this case the fundamental objective of traceability is to guarantee the renewable origin of the energy and thus differentiate the energy generated in a sustainable way.

Even so, since the initial experimentation, there are several utilities that have made different proofs of concept, and we must distinguish between (i) the traceability of energy from its point of origin, with information collected from the IIoT itself (smart meters of the power plant) or (ii) the traceability made retrospectively based on the data that the utility itself (not the machines) introduces in the blockchain. The first one gives a total guarantee and trustworthiness; in the second case, the reliability is given by the utility itself and does not have a superior value than a report signed by the energy company itself.

Equally important is the interoperability and sovereignty of the data in a smart grid in which different operators and manufacturers collaborate with a common industrial objective—the grid resilience—but with competing business objectives.

3.2 Prosumers and the value of energy data

We are facing a decentralization of energy production in part due to a new participant in the ecosystem, the prosumer [23]. Prosumers, unlike a traditional consumer—who simply consumes the energy provided by the smart grid—also are able to produce its own energy (**Figure 1**).

The proliferation of prosumers in the energy ecosystem is going to cause that these consumers will have more information and detail than the utility itself, something unthinkable until now where every kilowatt consumed by a home or company is accounted by the energy distributor.

These prosumers may be consuming energy without the utility being aware of it, but they must provide service to the user if it punctually needs more energy than is able to produce, either because of an increase in consumption, because the user has photovoltaic generation on the roof but the day is cloudy, etc.

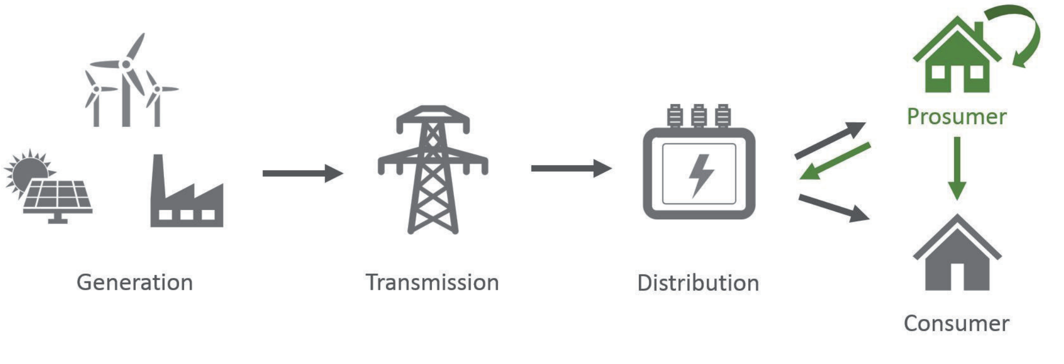

Figure 1.
Smart grid architecture and energy flows including prosumers.

In fact, these users have critical information to operate the system that will be extremely valuable for the stakeholders of the energy system in order to optimize their processes and ensure the stability of the network. It will allow them also to predict energy demand more accurately, avoiding deviations in the daily markets, improving the balance of the grid, and so on. Even in the case of large consumers, some companies offer optimized energy savings based on a baseline measurement.

However, the user is increasingly aware of the value of these data and not only because of their impact on the energy ecosystem. Starting from the detail of energy consumption, it is possible to infer a quite exhaustive profile of the user and, for example, to carry out a very good segmentation for marketing impacts.

The following transformation of the energy sector could be precisely based on the exploitation of these data, and thanks to blockchain, users could have control of them and therefore of their privacy.

4. The core value of blockchain in the industry

After analyzing the results of different proofs of concept and the benefits provided, we could say that blockchain can bring a number of differential features to Industry 4.0.

Perhaps the most popular is the decentralization of processes and business models. Blockchain provides by definition the intermediation between two parties in a reliable way [24] that is why many processes and organizations whose main value is the intermediation between parties can be optimized thanks to blockchain technology. We will therefore see intermediaries that adopt technology to be more efficient and robust, thus being able to offer a better service at more competitive prices or consortiums of companies that invest in creating themselves platforms to manage their relationships without depending on current intermediaries.

At the same time, blockchain offers an unalterable record of the history of any asset or industrial good, so traceability on that record is natural for blockchain technology. In addition, this record can be shared with third parties in an exercise of transparency of their processes.

Blockchain offers a really efficient synchronization of processes; it provides us with a single consensuated vision of the information related to industrial assets and processes, something really important in cases where different players and information systems must be coordinated to achieve a common industrial objective.

It is a perfect synchronization technology, resilient to network microcuts or failures of the systems involved in the industrial process. These usual deficiencies of the traditional technologies generate incoherencies in the data and consequently incorrect decision-making due to a bad synchronization of the information shared between the collaborating systems.

Finally, we should emphasize the blockchain capacity for process automation thanks to being a reliable source of information by offering a synchronized, consensual, and unalterable record on which we can also have a non-repudiation of the information, as each participant signs each of their transactions as if it were a digital contract in pdf.

As we have already commented, automating our industrial processes based on information from third parties is really risky if the source is not reliable. Unlike the technologies that we usually handle, blockchain offers us that certainty, even an evidence that can be used to claim a third party if the recorded information is not real or accurate.

5. Machine economy

The previous sections focused on explaining the results of proofs of concept and analysis of the applicability of blockchain in Industry 4.0, mainly in the improvement of processes and the creation of new products/services. In the current section, the focus will be to introduce a new economic paradigm that arises from the merger of industry, economy, and disruptive potential of blockchain, an area that precisely because it is still very experimental opens different lines of future research, the machine economy.

To understand the machine economy, we must first understand how we are facing a new paradigm of decentralization and disintermediation, which is already a small phenomenon in the world of currencies and will soon be a reality in many other areas. Entities such as eBay or Amazon already have to face the competition of OpenBazaar, an open-source blockchain software that offers near the same value as those companies. At the same time, the highly appreciated platform business models such as AirBNB or UBER are reflecting on what value to contribute beyond intermediation; otherwise they will be disintermediated by blockchain technology.

But the real potential of blockchain is not just to eliminate intermediaries; really these "cryptocurrencies" are digital tokens that represent a value [25]. Obviously the simplest application has been to create cryptocurrencies in which the blockchain issued those tokens instead of a central bank, but those tokens can represent whatever we want. Those tokens can represent the possession of a house or the identity of a person and all their history, but they can also represent the right to consume a service, to make decisions about the future of an organization, etc.

And this is where the real disruptive change begins; with the so-called crypto economy or token economy, an economy dominated by these tokens that is cryptographically protected by the blockchain will change the rules of the game and allow the total decentralization of the economy. In this new economy, the value will be tokenized, and these tokens will represent very different values as we commented.

This token economy is already emerging, it started with the cryptocurrencies, and we have also lived a new paradigm in the search for funding for business projects, in which under the name of initial coin offering (ICO) entrepreneurs with disruptive ideas find a new blue ocean of funding [26–28]. These entrepreneurs sell tokens that in many cases represent a service of that startup in the future, something similar to crowdfunding but totally globalized and without intermediaries who must manage those rights of future use of a platform. But these projects are going one step further than a simple decentralized crowdfunding; they are even devising new types of autonomous and decentralized organizations known as decentralized autonomous organizations (DAO) [29].

These organizations are created and financed by the community in order to offer an autonomous service thanks to blockchain. Imagine that we are tired of Google, Twitter or Facebook continues to earn money with our personal data, but we do not want to lose its functionality. Blockchain allows the community to finance and launch a new social media, or any other service, but without being managed by any for-profit entity, nor has a company registration number (CRN) in any country. It will be a virtual organization offering the service and relying on the community to perform those tasks that cannot perform by itself as investment decisions or strategy. So the community itself will run this virtual organization in a format similar to how a federation of worker cooperatives works.

This organization will be able to charge for its services and reinvest all the benefits in the development of improvements, new functionalities, etc. These organizations could also share part of those benefits with their promoters and community or simply offer these users free services. In this type of organizations, the "shareholder pact" has been programmed since its creation, "code is law." In fact, the change of these rules will have to be agreed by the community of users.

Machine economy is precisely to transfer this concept of DAO to the machines; we could be in front of a new evolution of the IoT. Let us imagine, for example, something we all know, a car. In a few years, it would not be difficult to imagine that there are a significant number of users who do not have a car and that there is a fleet of cars at their disposal.

These cars could be sovereigns; they could have their own identity, history, and even their own "wallet" to store digital value (tokens) that they will use to manage and store the value they receive by offering their transport services to passengers, as well as to pay for their recharges, tolls, cleaning, and maintenance.

In this way, we turn this car into an economic agent itself, with its own economy, self-sufficient, and even with its own business model. What's more, this car would foster new micro-service ecosystems around it.

Let us go a little deeper into tokenomics and the machine economy. These cars could be offered by a company, in a similar way to the traditional model. But thanks to blockchain, this could be financed as a kind of crowdfunding in which a DAO would be created with the initial investment, and gradually it would increase the fleet, grow geographically, and even replace old vehicles. The DAO would also be able to offer truly affordable costs to its customers and allow token owners governance, decision-making, and profit-sharing.

In this way, transport could be outsourced to the machines; the same outsourcing exercise could be carried out to other machines—robots—for the washing of these cars, their maintenance, carried out by robots and even the printing of parts on demand, the rubbish collection service, etc.

The token economy aims to return the power to the citizenry, and thanks to being a fully digital economy, machines can be active agents of it, thus generating their own economy, the economy of machines.

However, nowadays the machine economy is mainly an experimental concept that requires solving different challenges. Some of these research challenges are (i) secure hardware-based digital identity, (ii) interoperability an data sovereignty, (iii) more scalable and computationally efficient DLT architectures, or (iv) distributed machine governance model, between others.

6. Conclusions

In this chapter we have analyzed the general applicability of blockchain technology to the new paradigm of the Fourth Industrial Revolution, and due to its particular peculiarities, we have made a brief analysis of the specific case of the energy sector.

Based on our analysis and experimentation, we have selected three main lines of generic application for Industry 4.0: (i) traceability, (ii) interoperability and sovereignty of industrial data, and (iii) IIoT reliability. Moreover, in the case of energy, beyond exposing any particularity linked to IIoT or energy traceability, the analysis has focused on the prosumers and the value of their data in a new decentralized energy ecosystem.

As an outstanding contribution, the conclusions on the real value of blockchain in the industry should be pointed out, where abstracting from any specific scenario, the value of blockchain technology in this sector is analyzed in a universal way. The results are four main values of the technology, which in addition to being really the core of the analyzed cases could become applicable in other sectors. These differential features can be very useful to detect in an agile way if the application of the blockchain technology in a project contributes with a differential value in front of the rest of technologies of the state of the art.

Finally, we end with a reflection on a new paradigm that we have discovered during our research, and that may open different lines of future research, the Machine Economy.

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References

[1] Schuh G, Potente T, Wesch-Potente C, Weber AR, Prote JP. Collaboration mechanisms to increase productivity in the context of Industries 4.0. Procedia CIRP. 2014;**19**:51-56

[2] MarquesM,AgostinhoC,ZacharewiczG, Jardim-Gonçalves R. Decentralized decision support for intelligent manufacturing in Industry 4.0. Journal of Ambient Intelligence and Smart Environments. 2017;**9**(3):299-313

[3] Drescher D. Blockchain Basics. Berkeley, CA: Apress; 2017

[4] Banterle A, Stranieri S. The consequences of voluntary traceability system for supply chain relationships. An application of transaction cost economics. Food Policy. 2008;**33**(6):560-569

[5] Maro S, Steghöfer JP, Staron M. Software traceability in the automotive domain: Challenges and solutions. Journal of Systems and Software. 2018;**141**:85-110

[6] Farris M, Wittmann C, Hasty R. Aftermarket support and the supply chain: Exemplars and implications from the aerospace Industry. International Journal of Physical Distribution and Logistics Management. 2005;**35**(1):6-19

[7] Heyder M, Theuvsen L, Hollmann-Hespos T. Investments in tracking and tracing systems in the food Industry: A PLS analysis. Food Policy. 2012;**37**(1):102-113

[8] Kagermann H, Anderl R, Gausemeier J, Schuh G, Wahlster W. Industries 4.0 in a Global Context: Strategies for Cooperating with International Partners. New York: Herbert Utz Verlag. 2016. pp. 19-23

[9] Folinas D, Manikas I, Manos B. Traceability data management for food chains. British Food Journal. 2006;**108**(8):622-633

[10] Kagermann H. Change through digitization—Value creation in the age of Industry 4.0. In: Management of Permanent Change. Wiesbaden: Springer Gabler; 2015. pp. 23-45

[11] Otto B, ten Hompel M, Wrobel S. International data spaces. In: Digital Transformation. Berlin, Heidelberg: Springer Vieweg; 2019. pp. 109-128

[12] Lee J, Kao HA, Yang S. Service innovation and smart analytics for Industry 4.0 and big data environment. Procedia CIRP. 2014;**16**:3-8

[13] Zheng Z, Xie S, Dai H, Chen X, Wang H. An overview of blockchain technology: Architecture, consensus, and future trends. In: 2017 IEEE International Congress on Big Data (BigData Congress). IEEE; 2017, June. pp. 557-564

[14] Zyskind G, Nathan O, Pentland A. Enigma: Decentralized computation platform with guaranteed privacy. arXiv preprint arXiv:1506.03471; 2015

[15] Roos, J. Identity Management on the Blockchain. Chair of Network Architectures and Services, Department of Computer Science, Technische Universität München. 2018. p. 105. https://doi.org/10.2313/NET-2018-11-1_14

[16] Breivold HP, Sandström K. Internet of things for industrial automation--challenges and technical solutions. In: 2015 IEEE International Conference on Data Science and Data Intensive Systems. IEEE; 2015. pp. 532-539

[17] Jacobovitz O. Blockchain for Identity Management. The Lynne and William Frankel. Beer Sheva: Center for Computer Science Department of Computer Science. Ben-Gurion University; 2016

[18] Boudguiga A, Bouzerna N, Granboulan L, Olivereau A, Quesnel F, Roger A, et al. Towards better availability and accountability for iot updates by means of a blockchain. In: 2017 IEEE European Symposium on Security and Privacy Workshops (EuroS&PW). IEEE; 2017. pp. 50-58

[19] Rusi T, Lehto M. Cyber threats mega trends in cyber space. In: ICMLG 2017 5th International Conference on Management Leadership and Governance. Academic Conferences and Publishing Limited; 2017. p. 323

[20] Novo O. Blockchain meets IoT: An architecture for scalable access management in IoT. IEEE Internet of Things Journal. 2018;**5**(2):1184-1195

[21] Sharma PK, Chen MY, Park JH. A software defined fog node based distributed blockchain cloud architecture for IoT. IEEE Access. 2017;**6**:115-124

[22] Dorri A, Kanhere SS, Jurdak R. Towards an optimized blockchain for IoT. In: Proceedings of the Second International Conference on Internet-of-Things Design and Implementation. ACM; 2017, April. pp. 173-178

[23] Jacobs SB. The energy prosumer. Ecology Law Quarterly. 2016;**43**:519

[24] Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2008. http://bitcoin.org/bitcoin.pdf

[25] Hargrave J, Sahdev N, Feldmeier O. How value is created in tokenized assets. In: Blockchain Economics: Implications of Distributed Ledgers-Markets, Communications Networks, and Algorithmic Reality. ICCS 2018. Cambridge MA. Vol. 1. 2018. p. 125

[26] Catalini C, Gans JS. Initial Coin Offerings and the Value of Crypto Tokens (No. w24418). Cambridge, MA: National Bureau of Economic Research. 2018

[27] Adhami S, Giudici G, Martinazzi S. Why do businesses go crypto? An empirical analysis of initial coin offerings. Journal of Economics and Business. 2018;**100**:64-75

[28] Feng C, Li N, Lu B, Wong MH, Zhang M. Initial Coin Offerings, Blockchain Technology, and White Paper Disclosures; 2018

[29] Hsieh YY, Vergne JP. Bitcoin and the rise of decentralized autonomous organizations. Journal of Organization Design. 2018;**7**(1):14